any audible sound. This is, I believe, in accordance with the theory now held as to X-rays. We now have some information as to the mode of producing a local excitement so intense as to cause not merely atomic disturbance, but actual disruption of the atomic structure. Further developments of Sir Ernest Rutherford's experiments and of his theory of their explanation will be eagerly awaited.

A. Gray

ENGINEERING SCIENCE BEFORE, DURING AND AFTER THE WAR. III

The nations which have exerted the most influence in the war have been those which have developed to the greatest extent their resources, their manufactures and their commerce. As in the war, so in the civilization of mankind. But, viewing the present trend of developments in harnessing water-power and using up the fuel resources of the world for the use and convenience of man, one can not but realize that, failing new and unexpected discoveries in science, such as the harnessing of the latent molecular and atomic energy in matter, as foreshadowed by Clerk Maxwell, Kelvin, Rutherford and others, the great position of England can not be maintained for an indefinite period. At some time more or less remote—long before the exhaustion of our coal—the population will gradually migrate to those countries where the natural sources of energy are the most abundant.

Water-power and Coal.—The amount of available water-power in the British Isles is very small as compared with the total in other countries. According to the latest estimates, the total in the British Isles is less than 1,500,000 h.p., whereas Canada alone possesses more than 20,000,000 h.p., of which more than 2,000,000 h.p. have already been harnessed. In the rest of the British Empire there are upwards of 30,000,000 h.p., and in the remainder of the world at least 150,000,000 h.p., so that England herself possesses less than 1 per cent. of the water-power of the world. Further, it has been estimated that she only possesses 2½ per cent. of the whole coal of the world. To this question I would wish to direct our attention for a few minutes.

I have said that England owes her modern greatness to the early development of her coal. Upon it she must continue to depend almost exclusively for her heat and source of power, including that required for propelling her vast mercantile marine. Nevertheless, she is using up her resources in coal much more rapidly than most other countries are consuming theirs, and long before any near approach to exhaustion is reached her richer seams will have become impoverished, and the cost of mining so much increased that, given cheap transport, it might pay her better to import coal from richer fields of almost limitless extent belonging to foreign countries, and workable at a much lower cost than her own.

Let us endeavor to arrive at some approximate estimate of the economic value of the principal sources of power. The present average value of the royalties on coal in England is about $6 per ton, but to this must be added the profit derived from mining operations after paying royalties and providing for interest on the capital expended and for its redemption as wasting capital. After consultation with several leading experts in these matters, I have come to the conclusion that about 1*s* per ton represents the pre-war market value of coal in the seams in England.

It must, however, be remembered that, in addition, coal has a considerable value as a national asset, for on it depends the prosperity of the great industrial interests of the country, which contribute a large

portion of the wealth and revenue. From this point of view the present value of unmined coal seems not to have been sufficiently appreciated in the past, and that in the future it should be better appraised at its true value to the nation.

This question may be viewed from another aspect by making a comparison of the cost of producing a given amount of electrical power from coal and from water-power. Assuming that 1 h.p. of electrical energy maintained for one year had a pre-war value of £5, and that it requires about eight tons of average coal to produce it, we arrive at the price of 6*s.* 3*d.* per ton, *i. e.,* crediting the coal with half the cost. The capital required to mine eight tons of coal a year in England is difficult to estimate, but it may be taken approximately to be £5, and the capital for plant and machinery to convert it into electricity at £10, making a total of £15. In the case of water-power the average capital cost on the above basis is £40, including water rights (though in exceptionally favored districts much lower costs are recorded).

From these figures it appears that the average capital required to produce electrical power from coal is less than half the amount that is required in the case of water-power. The running costs, however, in connection with water-power are much less than those in respect of coal. Another interesting consideration it that the cost of harnessing all water-power of the world would be about £8,000,000,000, or equal to the cost of the war to England.

Dowling has estimated the total coal of the world as more than 7 million million tons, as whether we appraise it at 1*s.* or more per ton its present and prospective value is prodigious. For instance, at 6*s.* 3*d.* per ton it amounts to nearly one hundred times the cost of the war to all the belligerents.

In some foreign countries the capital costs of mining are far below the figures I have taken, and, as coal is transportable long distances and, generally speaking, electricity is not so at present, therefore it seems probable that capital will in the immediate future flow in increasing quantity to mining operations in foreign countries rather than to the development of, at any rate the more difficult and costly, water-power schemes. When, however, capital becomes more plentiful the lower running costs of water-power will prevail, with the result that water-power will then be rapidly developed.

As to the possible new sources of power, I have already mentioned molecular energy, but there is another alternative which appears to merit attention.

Bore Hole.—In my address to Section B in 1904 I discussed the question of sinking a shaft to a depth of twelve miles, which is about ten times the depth of any shaft in existence. The estimated cost was £5,000,000, and the time required about eighty-five years.

The method of cooling the air-locks to limit the barometric pressure on the miners and other precautions were described, and the project appeared feasible. One essential factor has, however, been queried by some persons: Would the rock at the great depth crush in and destroy the shaft? Subsequent to my address I wrote to *Nature,* suggesting that the question might be tested experimentally. Professor Frank D. Adams, of McGill University, Montreal, acting on the suggestion, has since carried out exhaustive experiments, published in the *Journal of Geology* for February, 1912, showing that in limestone a depth of fifteen miles is probably practicable, and that in granite a depth of thirty miles might be reached.

Little is at present known of the earth's

interior, except by inference from a study of its surface, upturned strata, shallow shafts, the velocity of transmission of seismic disturbances, its rigidity and specific gravity, and it seems reasonable to suggest that some attempt should be made to sink a shaft as deep as may be found practicable and at some locality selected by geologists as the most likely to afford useful information.

When we consider that the estimated cost of sinking a shaft to a depth of twelve miles, at present-day prices, is not much more than the cost of one day of the war to Great Britain alone, the expense seems trivial as compared with the possible knowledge that might be gained by an investigation into this unexplored region of the earth. It might, indeed, prove of inestimable value to science, and also throw additional light on the internal constitution of the earth in relation to minerals of high specific gravity.

In Italy, at Lardarello, bore-holes have been sunk which discharge large volumes of high pressure steam, which is being utilized to generate about 10,000 h.p. by turbines. At Solfatara, near Naples, a similar project is on foot to supply power to the great works in the district. It seems, indeed, probable that in volcanic regions a very large amount of power may be, in the future, obtained directly or indirectly by boring into the earth, and that the whole subject merits the most careful consideration.

While on the subject of obtaining power, may I digress for a few moments and describe an interesting phenomenon of a somewhat converse nature, *i. e.*, that of intense pressure produced by moderate forces closing up cavities in water?

A committee was appointed by the Admiralty in 1906 to investigate the cause of the rapid erosion of the propellers of some of the ships doing arduous duties. This was the first time that the problem had been systematically considered. The committee found that the erosion was due to the intense blows struck upon the blades of the propellers by the nuclei of vacuous cavities closing up against them. Though the pressure bringing the water together was only that of the atmosphere, yet it was proved that at the nucleus 20,000 atmospheres might be produced.

The phenomenon may be described as being analogous to the well-known fact that nearly all the energy of the arm that swings it is concentrated in the tag of a whip. It was shown that when water flowed into a conical tube which had been evacuated a pressure of more than 140 tons per square inch was recorded at the apex, which was capable of eroding brass, steel, and, in time, even the hardest steel. The phenomenon may occur under some conditions in rivers and waterfalls where the velocity exceeds 50 feet per second, and it is probably as great a source of erosion as by the washing down of boulders and pebbles. Then again, when waves beat on a rocky shore, under some conditions, intense hydraulic pressures will occur, quite sufficient of themselves to crush the rock and to open out narrow fissures into caves.

Research.—The whole question of the future resources of the empire is, I venture to think, one which demands the serious attention of all men of science. It should be attacked in a comprehensive manner, and with that insistence which has been so notable in connection with the efforts of British investigators in the past. In such a task some people might suggest we need encouragement and assistance from the government of the country. Surely we have it. As many here know, a great experimental step towards the practical realization of Solomon's House as prefigured by Francis Bacon in the *New*

Atlantis is being made by the government at the present time. The inception, constitution and methods of procedure of the department, which was constituted in 1915, were fully described by Sir Frank Heath in his paper to the Royal Society of Arts last February, and it was there stated by Lord Crewe that, so far as he knew, this was the only country in which a government department of research existed.[4]

It is obvious that the work of a department of this kind must be one of gradual development with small beginnings in order that it may be sound and lasting. The work commenced by assisting a number of researches conducted by scientific and professional societies which were languishing as a result of the war, and grants were also made to the National Physical Laboratory and to the Central School of Pottery at Stoke-on-Trent. The grants for investigation and research for the year 1916–17 totalled £11,055, and for the present year are anticipated to be £93,570. The total income of the National Physical Laboratory in 1913–14 was £43,713, and, owing to the great enlargement of the laboratory, the total estimate of the Research Department for this service during the current year is £154,650.

Another important part of the work of the department has been to foster and to aid financially associations of the trades for the purpose of research. Nine of these associations are already at work; eight more are approved, and will probably be at work within the next two months; and another twelve are in the earlier stage of formation. There are also signs of great increase of research by individual factories. Whether this is due to the indirect influence of the Research Department or to a change in public opinion and a more general recognition of the importance of scientific industrial research it is difficult to say.

The possibility of the uncontrolled use on the part of a nation of the power which science has placed within its reach is so great a menace to civilization[5] that the ardent wish of all reasonable people is to possess some radical means of prevention through the establishment of some form of wide and powerful control. Has not science forged the remedy by making the world a smaller arena for the activities of civilization, by reducing distance in terms of time? Alliances and unions, which have successfully controlled and stimulated republics of heterogeneous races during the last century, will therefore have become possible on a wider and grander scale, thus uniting all civilized nations in a great league to maintain order, security and freedom for every individual and for every state and nation liberty to devote their energies to the controlling of the great forces of nature for the use and convenience of man, instead of applying them to the killing of each other.

Many of us remember the president's banner at the Manchester meeting in 1915, where science is allegorically represented by a sorrowful figure covering her eyes from the sight of the guns in the foreground. This year science is represented in her more joyful mien, encouraging the arts and industries. It is to be sincerely hoped that the future will justify our present optimism.

CHARLES A. PARSONS

[4] The Italian government are now establishing a National Council for Research, and a bill is before the French Chamber for the establishment of a National Office of Scientific, Industrial and Agricultural Research and Inventions.

[5] For instance, it might some day be discovered how to liberate instantaneously the energy in radium, and radium contains 2,500,000 times the energy of the same weight of T.N.T.